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Abstract

The authors use simple new finite-sample methods to test the empirical relevance of the New Keynesian Phillips curve (NKPC) equation. Unlike tests based on the generalized method of moments, the generalized Anderson-Rubin (1949) tests are immune to the presence of weak instruments and allow, by construction, the identification status of a model to be assessed. The authors illustrate their results using Gali and Gertler's (1999) NKPC specifications and data, as well as a survey-based inflation-expectation series from the Federal Reserve Bank of Philadelphia.

The test the authors use rejects Gali and Gertler's estimates (conditional on the latters' choice of instruments). Nevertheless, and in contrast with results obtained by Ma (2002), the authors do obtain relatively informative confidence sets. This provides support for NKPC equations and illustrates the usefulness of using exact procedures in estimations based on instrumental variables. The authors' results also reveal that the least well-identified parameter is ω; namely, the proportion of firms that do not adjust their prices in period t.

JEL classification: C13, C52, E31
Bank classification: Econometric and statistical methods; Inflation and prices

Résumé

Les auteures font appel aux nouvelles méthodes d'inférence simples adaptées aux échantillons finis pour tester la validité empirique de la nouvelle courbe de Phillips keynésienne. Contrairement aux tests fondés sur la méthode des moments généralisés, les tests généralisés d'Anderson-Rubin (1949) ne sont pas sensibles à la présence de variables instrumentales médiocres et permettent, de par leur construction, d'évaluer la qualité de l'identification d'un modèle. Aux fins de leur démonstration, les auteures utilisent les données de Gali et Gertler (1999) et la formulation que ceux-ci proposent pour la nouvelle courbe de Phillips keynésienne, ainsi que les données d'une enquête de la Banque fédérale de réserve de Philadelphie sur les attentes d'inflation.

Le test appliqué par les auteures conduit au rejet des estimations de Gali and Gertler, du moins pour le même ensemble de variables instrumentales. En revanche, les intervalles de confiance qu'elles obtiennent pour les paramètres sont relativement étroits, ce qui tranche avec les résultats de Ma (2002) et accrédite la validité de la nouvelle courbe de Phillips keynésienne. Il semble donc que l'emploi d'une procédure d'estimation exacte soit utile lorsqu'on a recours à des variables instrumentales. De tous les paramètres examinés par les auteures, le moins bien identifié est ω, soit le pourcentage d'entreprises qui ne rajustent pas leurs prix à la période t.

Classification JEL : C13, C52, E31
Classification de la Banque : Méthodes économétriques et statistiques; Inflation et prix

1. Introduction

The New Keynesian Phillips curve (NKPC) equation resulted from efforts in recent years to model the short-run dynamics of inflation starting from optimization principles. In its benchmark form, this equation stipulates that inflation at time t is a function of expected future inflation and current marginal costs. With its clearly elucidated theoretical foundations, the NKPC possesses a straightforward structural interpretation and therefore has a strong theoretical advantage over the traditional reduced-form Phillips curve (which is justified only statistically).

Confronting the NKPC with the data, however, has raised several issues.[1] In particular, modelling the marginal-cost variable is a fundamental problem. Whereas, under some conditions, the output-gap series is a natural proxy for this variable, studies that use gap measures reveal two empirical puzzles: (i) the coefficient on the output gap is estimated to be negative when theoretically it should be positive, and (ii) adding lagged inflation to the above model in an ad hoc manner seems to correct the estimated sign problem, suggesting that, contrary to what the theory predicts, past inflation matters.[2]

These puzzles have spurred further theoretical and empirical research. For instance, Gali and Gertler (1999) modify the standard NKPC theoretical formulation by allowing a proportion of firms to use a rule of thumb when setting prices for their goods (rather than allowing all firms to set prices in a rational manner). The latter modification provides a theoretical justification for the presence of an inflation lag in the first-order condition. Models that incorporate the above features are referred to as *hybrid* NKPC models.

Empirical research has focused on proposing improved proxies for the marginal-cost variable. For example, Gali and Gertler (1999) suggest that measures of marginal cost derived from a production function be used, instead of relying on output gaps that possibly have been poorly measured. A

[1] See, for example, Gali and Gertler (1999), Gali, Gertler, and Lopez-Salido (2001), and the references cited therein.

[2] See, for example, Fuhrer and Moore (1995), Roberts (1997) and Fuhrer (1997).

generalized method of moments (GMM) estimation of hybrid NKPCs that have these new marginal-cost measures yields the correct sign on that variable, and the model is not rejected according to Hansen's J-test. Moreover, the choice for the marginal-cost proxy seems to affect the estimated weight of the backward- and forward-looking terms in the equation.[3]

While the above results appear encouraging, it is important to note that the recent literature on instrumental variable (IV)-based inference casts serious doubts on the reliability of standard inference procedures.[4] These studies demonstrate that standard asymptotic procedures are fundamentally flawed and lead to serious overrejections; these problems, rather than being small-sample related, occur with fairly large sample sizes, since they are caused by asymptotic failures. In particular, Dufour (1997) shows that usual t-type tests, based on common IV estimators, have significance levels that may deviate arbitrarily from their nominal levels, since it is not possible to bound their null distributions.

To circumvent difficulties related to weak instruments, the above-cited work on IV-based inference focuses on three main directions: (i) refinements in asymptotic analysis, which include the local-to-zero or local-to-unity frameworks (e.g., Staiger and Stock 1997; Wang and Zivot 1998; Stock and Wright 2000), (ii) proposals of asymptotic approximations that hold regardless of whether instruments are weak (e.g,. Kleibergen 2002; Moreira 2002), and (iii) development of new finite-sample methods based on proper pivots – that is, finding statistics that have null distributions that are either free of nuisance parameters or are bounded by distributions that are free of them (e.g., Dufour 1997; Dufour and Jasiak 2001; Dufour and Khalaf 2002; Dufour and Taamouti 2003b,c).

In this paper, we focus on the new finite-sample methods to test the empirical relevance of the NKPC. These methods allow, by construction, the identification status of a model to be assessed. Another major advantage is

[3]For example, see Gali, Gertler, and Lopez-Salido (2001) and Gagnon and Khan (2001).

[4]See, for example, Dufour (2004), Stock, Wright, and Yogo (2002), and the references cited therein.

that they are valid in samples typical of macroeconomic data – i.e., samples that are fairly small. Furthermore, they can provide fairly detailed information regarding the nature of potential underidentification, thereby suggesting useful theory modifications. This is an advantage over Stock and Wright's (2000) asymptotic methods, which do not provide such information directly.

Specifically, we apply the econometric methods presented in Dufour and Jasiak (2001), which are generalizations of the Anderson-Rubin (1949) statistics. Our results are illustrated using Gali and Gertler's NKPC specifications and data. In section 2, we reproduce the NKPC models that were developed by Gali and Gertler (1999) and describe their results; we also describe the results of a recent re-evaluation of these specifications by Ma (2002). In section 3, we describe the generalized Anderson-Rubin (hereafter, AR) test. Section 4 documents and discusses the results of the AR test applications to the above NKPC specifications. Section 5 concludes.

2. Gali and Gertler's NKPC Models

In Gali and Gertler's benchmark specification, all price-setting firms are forward looking in a monopolistically competitive environment. Thus, inflation, π_t, is a function of the next period's expected inflation, $E_t\pi_{t+1}$, and real marginal costs, s_t (expressed as a percentage deviation with respect to its steady-state value). Specifically, the model is written as:

$$\pi_t = \lambda_1 s_t + \beta E_t \pi_{t+1}, \tag{1}$$

with

$$\lambda_1 = \frac{(1-\theta)(1-\beta\theta)}{\theta}, \tag{2}$$

where θ is the proportion of firms that do not adjust their prices in period t, β is the subjective discount rate, and $E_t\pi_{t+1}$ is the value of inflation for the next period that is expected at time t.

In contrast, Gali and Gertler's hybrid specification assumes that some of the firms use a rule of thumb when setting their prices. The proportion of

such firms (referred to as the backward-looking price-setters) is given by ω. In this case, the model is written as:

$$\pi_t = \lambda_2 s_t + \gamma_f E_t \pi_{t+1} + \gamma_b \pi_{t-1}, \tag{3}$$

with

$$\begin{aligned} \lambda_2 &= \frac{(1-\omega)(1-\theta)(1-\beta\theta)}{\theta + \omega - \omega\theta + \omega\beta\theta} \\ \gamma_f &= \frac{\beta\theta}{\theta + \omega - \omega\theta + \omega\beta\theta} \\ \gamma_b &= \frac{\omega}{\theta + \omega - \omega\theta + \omega\beta\theta}, \end{aligned} \tag{4}$$

where π_{t-1} is the inflation lag, γ_f is the forward-looking component of inflation, and γ_b is its backward-looking part.

Gali and Gertler assume rational expectations and rewrite the above NKPC models in terms of orthogonality conditions estimated by standard two-step GMM. Because of small-sample concerns, each rewritten model is normalized in two ways: (i) non-linearities are minimized (denoted as specification (1)), and (ii) the inflation coefficient is set equal to one (denoted as specification (2)).

Quarterly U.S. data are used, with π_t measured by the percentage change in the GDP deflator, and real marginal costs given by the logarithm of the labour income share.[5] The instruments used include four lags of inflation, labour share, commodity-price inflation, wage inflation, the long-short interest rate spread, and output gap (measured by a detrended log GDP).

For their benchmark model, Gali and Gertler find values of (θ, β) equal to (0.83, 0.93) and (0.88, 0.94) for their specifications (1) and (2), respectively. Constraining β to 1 yields similar results; namely, $\theta = 0.83$ in (1) and $\theta = 0.92$ in (2). The implied slope coefficients on the marginal-cost variable for all these cases are positive and significant – judging from the IV-based

[5]They also report results for the case where inflation is measured by the non-farm deflator. These yield similar outcomes to those based on the GDP total deflator measure.

asymptotic standard errors, and the fact that the overidentifying restrictions are not rejected according to the J-test. For their hybrid model, the same normalizations and instrument set are used. In this case, the obtained values for ω, θ, and β are (0.27, 0.81, 0.89) and (0.49, 0.83, 0.91) for specifications (1) and (2), respectively. In the restricted cases, these are (0.24, 0.80, 1.00) and (0.52, 0.84, 1.00), respectively. Again, the implied slopes are all positive and found to be significant.

Based on these and some additional GMM estimations carried out for robustness, Gali and Gertler conclude that there is good empirical support for the NKPC, and, furthermore, that the forward-looking component of inflation is more important than the backward-looking part.

Despite their significance, it is important to be wary of GMM-based results, because the severity of weak-instruments effects is now well understood in econometrics.[6] Given these concerns, Ma (2002) uses asymptotic test statistics developed by Stock and Wright (2000) to re-evaluate the empirical relevance of the NKPC specifications. These asymptotic methods account for the presence of weak instruments and provide corrected confidence intervals for the GMM-estimated parameters.

Ma first notes that the benchmark model presents a theoretical identification problem; namely, there is an observational equivalence between sets (β, θ) and $(\beta, 1/\beta\theta)$. Thus, more than one parameter combination satisfies the GMM minimization criterion. In other words, the objective function being solved by GMM (and which is concentrated with respect to θ) is nonquadratic. Therefore, conventional tests, such as those applied by Gali and Gertler, do not provide accurate information on the precision of GMM estimates.

Turning to the estimates from the hybrid model, Ma calculates the corrected confidence set according to the method proposed by Stock and Wright

[6]Examples include Dufour (1997), Staiger and Stock (1997), Wang and Zivot (1998), Stock and Wright (2000), Dufour and Jasiak (2001), Stock, Wright, and Yogo (2002), Kleibergen and Zivot (2003), Khalaf and Kichian (2002), Dufour and Khalaf (2003), Dufour and Taamouti (2003b,c), and Dufour (2004).

(2000). He finds that the 90 per cent S-set is particularly large, including all parameter values between [0, 3] for two of the parameters, and [0, 8] for the third. That is, all parameter combinations derived from these value ranges are compatible with the model. This is a clear indication of weak identification in this model.

Thus, the validity of Gali and Gertler's GMM-based estimates is in question; however, Stock and Wright's intervals provide little concrete direction for theoretical research. On the other hand, recent finite-sample methods that also deal with the possible presence of weak instruments may be able to provide such direction. In section 3, we present a test strategy that belongs in the finite-sample category.

3. The AR Test

The AR test has recently received renewed interest.[7] In its generalized form – developed by Dufour and Jasiak (2001) – it is applicable to univariate models that use limited information, and where one or more of the right-hand-side variables are possibly endogenous.

More formally, consider a limited-information simultaneous-equations system:

$$y = Y\delta + X_1\kappa + u, \tag{5}$$

where y is an $n \times 1$ dependent variable, Y is an $n \times m$ matrix of endogenous variables, X_1 is an $n \times k_1$ matrix of exogenous variables, and u is an error term that satisfies standard regularity conditions typical of IV regressions; see Dufour and Jasiak (2001).

In this context, consider hypotheses of the form

$$H_0 : \delta = \delta^0. \tag{6}$$

[7] See, for example, Dufour (1997), Staiger and Stock (1997), Dufour and Jasiak (2001), Dufour and Khalaf (2003), and Dufour and Taamouti (2003b,c).

Define $\tilde{y} = y - Y\delta^0$ so that, under the null hypothesis, (6) implies that

$$\tilde{y} = X_1\kappa + u. \tag{7}$$

In view of this, the AR test assesses the exclusion of X_2 (of size $n \times k_2$) in the regression of $\tilde{y}$ on X_1 and X_2, which can be conducted using the standard F-test or its chi-square asymptotic variant; see Dufour and Jasiak (2001). Let $X = (X_1, X_2)$, and define

$$\begin{aligned} M &= I - X(X'X)^{-1}X', \\ M_1 &= I - X_1(X_1'X_1)^{-1}X_1'. \end{aligned}$$

The statistic then takes the form

$$AR = \frac{\left[(y - Y\delta^0)' M_1 (y - Y\delta^0) - (y - Y\delta^0)' M (y - Y\delta^0)\right] / k_2}{(y - Y\delta^0)' M (y - Y\delta^0) / (n - k_1 - k_2)}. \tag{8}$$

Under the null hypothesis, and imposing strong exogeneity and identically, independently distributed (i.i.d.) normal errors, $AR \sim F(k_2, n - k_1 - k_2)$; the normality and i.i.d. hypotheses can be relaxed so that, under standard regularity conditions and weakly exogenous regressors, $(k_2 \times AR) \overset{asy}{\sim} \chi^2(k_2)$.

The test can be readily extended to accommodate additional constraints on the coefficients of the exogenous variables; see Maddala (1974), Dufour and Jasiak (2001), Dufour and Taamouti (2003b,c), and Dufour (2004). Specifically, consider a hypothesis of the form

$$H_0 : \delta = \delta^0, \quad \kappa_1 = \kappa_1^0, \tag{9}$$

where κ_1 is a subset of κ; i.e., $\kappa = (\kappa_1', \kappa_2')'$. Partition the matrix X_1 (into X_{11} and X_{12} submatrices) accordingly, and let

$$\check{y} = y - Y\delta^0 - X_{11}\kappa_1. \tag{10}$$

The restricted model then becomes

$$\check{y} = X_{12}\kappa_{12} + u, \tag{11}$$

and the test can be carried out as above.

While the test in its original form was derived for the case where the first-stage regression is linear, Dufour and Taamouti (2003b,c) show that it is in fact robust to: (i) the specification of the model for Y, and (ii) excluded instruments; in other words, the test is valid regardless of whether the first-stage regression is linear, and whether the matrix X_2 includes all available instruments. As argued in Dufour (2004), since one is never sure that all instruments have been accounted for, the latter property is quite important. Most importantly, this test (and several variants discussed in Dufour 2004) is the only truly pivotal statistic whose properties in finite samples are robust to the quality of instruments.

4. Applications of the AR Test

The econometric models that we use for the AR applications are Gali and Gertler's benchmark and hybrid models in equation (1) and (3), respectively, with $E_t\pi_{t+1}$ given by a survey measure of inflation expectations, $\tilde{\pi}_{t+1}$. The Federal Reserve Bank of Philadelphia publishes quarterly mean forecasts of the next quarter's U.S. GDP implicit price deflator, which we first-difference to obtain our inflation-expectations series.[8] A measurement-error term, u_t, is added to the equation to reflect the fact that the expectations variable is a proxy. Thus, our econometric equivalents of Gali and Gertler's models are:

$$\pi_t = \lambda_1 s_t + \beta\tilde{\pi}_{t+1} + u_t, \tag{12}$$

and

$$\pi_t = \lambda_2 s_t + \gamma_f\tilde{\pi}_{t+1} + \gamma_b\pi_{t-1} + u_t, \tag{13}$$

where λ_1, λ_2, γ_f, and γ_b are defined in equations (2) and (4).

In this framework, and for both the benchmark and hybrid models, $y = \pi_t$, $Y = (s_t, \tilde{\pi}_{t+1})'$, and X_2 is the 24-variable set of instruments used by Gali and

[8]Source: http://www.phil.frb.org/econ/spf/index.html.

Gertler. In addition, X_1 is zero in the benchmark case, and equal to π_{t-1} in the hybrid case.

We test Gali and Gertler's (1999) estimates for the benchmark and hybrid models, and for both specifications, using their instrument set each time.[9] For example, suppose we want to test their benchmark estimates for model specification (1). We impose $\theta = 0.83, \beta = 0.93$, and calculate the corresponding slope value, which is $\lambda_0 = 0.05$. The null hypothesis for the AR test is then given by $H_0 : \lambda_0 = 0.05$ and $\beta_0 = 0.93$. Constructing $\tilde{y}$, we regress it on all of Gali and Gertler's instruments. Computing the M and M_1 matrices, we obtain the value of the AR statistic according to equation (8). We have $n = 112$ observations and $k_2 = 24$ instruments. The statistic is therefore compared with the $F(24, 88)$ distribution, and in the case where the normality and i.i.d. hypotheses are relaxed, $24\times$AR is compared with a $\chi^2(24)$.

The results are reported in Table 1, which shows that all of Gali and Gertler's GMM estimates are decisively rejected at the 5 per cent level. In other words, given the instrument set that Gali and Gertler use, both their benchmark and hybrid models are strongly rejected by the data, regardless of whether specification (1) or (2) estimates are used, and whether the β parameter is restricted to equal 1.

We then ask whether, for the same instrument set, there are any parameter combinations for which the models are not rejected. We conduct such a grid search for each of the benchmark and hybrid models, allowing the range (0, 1) as the admissible space for ω, θ, and β, and varying these values with increments of 0.1. We find that all parameter combinations reject the model at the 5 per cent level, whether the benchmark or the hybrid equation is being tested.

This conclusion is in striking contrast with the findings of Ma (2002), although his and our results emphasize the weak-instruments problem. That is, while Stock and Wright's asymptotic test finds that all parameter combi-

[9]Because an expectations variable is present, our sample starts in 1970Q1.

nations do not reject the model, we find that all of them actually do reject it.[10]

It is evident that whether a model is rejected depends on the instruments that are used to specify it. The issue of which instruments to use is quite difficult and beyond the scope of this study. However, an easy way to understand the relevance of various instrument sets is to specify the model with each and then test it. We consider seven different instrument sets, each consisting of four lags of a variable amongst the following: GDP deflator inflation, wage inflation, commodity price inflation, labour income share, the long-short interest rate spread, quadratically detrended output gap, and cubically detrended output gap.[11] For each of these sets, we conduct grid searches for the benchmark and hybrid models again, always admitting a (0, 1) range for each of ω, θ, and β, and still varying the parameter values by increments of 0.1.

The results are shown in Tables 2 to 6b. Table 2 shows, for the seven instrument sets, those combinations of β and θ values that do not reject the tested specification. The remaining tables show results for the hybrid model. Tables 3a and 3b show the outcomes for estimations over the full sample, while Tables 4a and 4b, 5a and 5b, and 6a and 6b show results for non-intersecting subsamples (1970Q1 to 1979Q4, 1980Q1 to 1989Q4, 1990Q1 to 1997Q4). In each case, to save space, we report the results with four of the instrument sets.[12]

The overall results show that there are parameter combinations for which

[10]There is a slight difference between our two instrument sets: Ma's set includes a constant and has no fourth lag for each of the three variables in levels.

[11]For our output-gap measure, and for all the tests we conduct, rather than detrending the log of GDP using the full sample, n, we proceed iteratively: to obtain the value of the gap at time t, we detrend GDP with data ending in t. We then extend the sample by one more observation and re-estimate the trend. This is used to detrend GDP and yields a value for the gap at time $t+1$. This process is repeated until the end of the sample. In this fashion, our gap measures at time t do not use information beyond that period and can therefore be used as valid instruments.

[12]The remaining tables are available upon request.

a given model is rejected, and others for which it is not. Some instrument sets appear to have more informational content than others (i.e., they yield a smaller set of parameter combinations that do not reject the model). These results are somewhat positive for macroeconomic theorists, because they indicate that the NKPC models are not rejected outright. But while the scope of the identification issue is slightly less dramatic with our results than with those suggested by Stock and Wright's method, our tables do indeed indicate the presence of pervasive identification problems. For instance, in the benchmark model (Table 2), the instrument sets in columns 1 to 4 and in column 6 show that there are many parameter combinations for which the model is valid. Similarly, in the hybrid model case, there are numerous parameter combinations that do not reject the NKPC specification.

Important additional information can be gained from the tables regarding the direction in which theoretical research should be oriented. Particularly for the hybrid model case (Tables 3a to 6b), some patterns emerge: (i) as the value of θ increases, the values for β decrease, and (ii) results are more restrictive when ω is not too high or too low. Based on these, we can see that, if one is willing to assume a range for the subjective discount rate that is economically meaningful (say, values ranging from 0.8 to 1), then the space of admissible parameter values is greatly reduced: thus θ is almost never above 0.4, and it is lower when ω is either high or low. That is, the ω parameter is less well-identified than θ, which implies that better ways must be found of characterizing the inertia in inflation dynamics.

The information in the tables has been summarized in Figures 1 to 9. For each model, we graph the parameter combinations that do not reject the model when the latter is specified using four different instrument sets. Figure 1 shows graphs of the benchmark model for the instrument sets: lags 1 to 4 of inflation, lags 1 to 4 of wage inflation, lags 1 to 4 of the long-short interest rate spread, and lags 1 to 4 of labour income share. Figure 2 shows graphs of the hybrid model with the same instrument sets. Column 1 shows graphs of θ and β for all values of ω considered, while the subsequent columns

show θ and β for $\omega = 0.2$, $\omega = 0.5$, and $\omega = 0.8$, respectively. Figures 4, 6, and 8 each depict graphs that are similar to Figure 2, but for subsamples 1970Q1 to 1979Q4, 1980Q1 to 1989Q4, and 1990Q1 to 1997Q4, respectively. In those cases, however, we show results with lags 1 to 4 for the quadratically detrended output gap, rather than lags 1 to 4 for the labour income share, because the former are more interesting. Figures 3, 5, 7, and 9 show graphs that correspond to Figures 2, 4, 6, and 8, respectively, but with β constrained to be equal to or above 0.8, which is economically more meaningful.

The graphs show more clearly the patterns in the results that were reported in the tables. Furthermore, the subsample graphs show clear evidence of parameter instability. In particular, whereas the results for the quadratically detrended output instrument set show that all parameter combinations reject the model in the 1970s, results with the same instrument set show non-rejections for the 1980s and 1990s.

5. Conclusion

We have used new finite-sample methods to test the empirical relevance of the New Keynesian Phillips curve equation. We have illustrated our results using Gali and Gertler's (1999) NKPC specifications and data, as well as a survey-based inflation-expectation series from the Federal Reserve Bank of Philadelphia.

Our test rejects Gali and Gertler's estimates (conditional on their choice of instruments). Nevertheless, we obtain relatively informative confidence sets. The latter is in contrast with the results obtained by Ma (2002), who uses Stock and Wright's methods to obtain confidence sets that account for weak identification in GMM-estimated models. That is, we find the scope of the identification problem less dramatic than does Ma (2002). Indeed, our results reveal that the least well-identified parameter is ω; namely, the proportion of firms that do not adjust their prices in period t.

Of course, despite its desirable statistical properties, the generalized AR

test that we apply provides no guidance regarding the choice of instruments. Methods for the selection of optimal instruments are currently being developed.

Bibliography

Anderson, T.W. and H. Rubin. 1949. "Estimation of the Parameters of a Single Equation in a Complete System of Stochastic Equations." *Annals of Mathematical Statistics* 20: 46-63.

Dufour, J.-M. 1997. "Some Impossibility Theorems in Econometrics, with Applications to Structural and Dynamic Models." *Econometrica* 65: 1365-89.

——. 2004. "Identification, Weak Instruments, and Statistical Inference in Econometrics." *Canadian Journal of Economics* 36, forthcoming.

Dufour, J.-M. and J. Jasiak. 2001. "Finite Sample Limited Information Inference Methods for Structural Equations and Models with Generated Regressors." *International Economic Review* 42: 815-43.

Dufour, J.-M. and L. Khalaf. 2002. "Simulation-Based Finite and Large Sample Tests in Multivariate Regressions." *Journal of Econometrics* 111(2): 303-22.

——. 2003. "Simulation-Based Finite-Sample Inference in Simultaneous Equations." Technical Report, C.R.D.E. Université de Montréal.

Dufour, J.-M. and M. Taamouti. 2003a. "On Methods for Selecting Instruments." Technical Report, C.R.D.E. Université de Montréal.

——. 2003b. "Point-Optimal Instruments and Generalized Anderson-Rubin Procedures for Nonlinear Models." Technical Report, C.R.D.E. Université de Montréal.

——. 2003c. "Projection-Based Statistical Inference in Linear Structural Models with Possibly Weak Instruments." Technical Report, C.R.D.E. Université de Montréal.

Fuhrer, J. 1997. "The (Un)Importance of Forward-Looking Behavior in Price Specifications." *Journal of Money, Credit and Banking* 29: 338-50.

Fuhrer, J. and G. Moore. 1995. "Inflation Persistence." *Quarterly Journal of Economics* 110: 127-59.

Gagnon, E. and H. Khan. 2001. "New Phillips Curves with Alternative Marginal Cost Measures, for Canada, the U.S., and the Euro Area." Bank of Canada Working Paper No. 2001-25.

Gali, J. and M. Gertler. 1999. "Inflation Dynamics: A Structural Econometric Analysis." *Journal of Monetary Economics* 44: 195-222.

Gali, J., M. Gertler, and D. Lopez-Salido. 2001. "European Inflation Dynamics." *European Economic Review* 45: 1237-70.

Khalaf, L. and M. Kichian. 2002. "Simulation-Based Tests of Pricing-to-Market." In *Computational Methods in Decision-Making, Economics and Finance*, edited by E. Kontoghiorghes, B. Rustem, and S. Siokos, Chapter 29, 583-603. The Kluwer Applied Optimization Series.

Kleibergen, F. 2002. "Pivotal Statistics for Testing Structural Parameters in Instrumental Variables Regressions." *Econometrica* 70(5): 1781-804.

Kleibergen, F. and E. Zivot. 2003. "Bayesian and Classical Approaches to Instrumental Variable Regression." *Journal of Econometrics* 114(1): 29-72.

Ma, A. 2002. "GMM Estimation of the New Phillips Curve." *Economics Letters* 76: 411-17.

Maddala, G.S. 1974. "Some Small Sample Evidence on Tests of Significance in Simultaneous Equations Models." *Econometrica* 60: 841-51.

Moreira, M. J. 2002. "A General Theory of Hypothesis Testing in the Simultaneous Equations Model." Working Paper, Department of Economics, MIT.

Roberts, J. 1997. "Is Inflation Sticky?" *Journal of Monetary Economics* 39: 173-96.

Staiger, D. and J. H. Stock. 1997. "Instrumental Variables Regression with Weak Instruments." *Econometrica* 65: 557-86.

Stock, J. H. and J. Wright. 2000. "GMM With Weak Identification." *Econometrica* 68: 1055-96.

Stock, J. H., J. Wright, and M. Yogo. 2002. "A Survey of Weak Instruments and Weak Identification in Generalized Method of Moments." *Journal of Business and Economic Statistics* 20(4): 518-29.

Wang, J. and E. Zivot. 1998. "Inference on Structural Parameters in Instrumental Variables Regression with Weak Instruments." *Econometrica* 66: 1389-1404.

Zivot, E., R. Startz, and C. Nelson. 1998. "Valid Confidence Intervals and Inference in the Presence of Weak Instruments." *International Economic Review* 39: 1119-44.

Table 1: AR Test Results on Gali and Gertler's Models

Tested Model	Spec.	Restr	Data Sample	D.F.	F-stat (p-value)	Chi-stat (p-value)
Benchmark	(1)	-	70:1-97:4	88	8.77 (<)	210.54 (<)
Benchmark	(2)	-	70:1-97:4	88	9.31 (<)	223.61 (<)
Benchmark	(1)	yes	70:1-97:4	88	11.57 (<)	277.59 (<)
Benchmark	(2)	yes	70:1-97:4	88	11.55 (<)	277.27 (<)
Hybrid	(1)	-	70:1-97:4	87	7.98 (<)	199.42 (<)
Hybrid	(2)	-	70:1-97:4	87	13.55 (<)	338.83 (<)
Hybrid	(1)	yes	70:1-97:4	87	11.05 (<)	276.26 (<)
Hybrid	(2)	yes	70:1-97:4	87	17.41 (<)	435.28 (<)
Hybrid	(1)	-	70:1-89:4	55	4.73 (<)	118.21 (<)
Hybrid	(1)	yes	70:1-89:4	55	8.19 (<)	204.72 (<)
Hybrid	(2)	-	80:1-97:4	47	7.01 (<)	175.29 (<)
Hybrid	(2)	yes	80:1-97:4	47	14.13 (<)	353.19 (<)

Note: D.F. is degrees of freedom, Spec is specification, Restr is restricted, and the symbol "<" indicates values that are less than 10^{-5}.

Table 2: Benchmark Model - Parameter Grid Search Results
Parameter Combna tions that Do Not Reject H_0 - Full Sample

	dw_1 - dw_4	sp_1 - sp_4	dp_1 - dp_4	s_1 - s_4	gq_1 - gq_4	dc_1 - dc_4	gc_1 - gc_4
$\theta = 0.0$	(0 - 0.8)	(0 - 1)	(0 - 0.5)	-	-	(0 - 1)	-
$\theta = 0.1$	(0.3 - 0.6)	(0.6 - 1)	(0.3 - 0.6)	-	-	(0 - 1)	-
$\theta = 0.2$	(0.5 - 0.6)	(0.7 - 1)	(0.5 - 0.6)	(0 - 0.1)	-	(0 - 1)	-
$\theta = 0.3$	0.6	(0.7 -0.9)	0.6	(0 - 0.3)	-	(0 - 1)	-
$\theta = 0.4$	0.6	(0.7 -0.8)	0.6	(0 - 0.5)	-	(0 - 1)	-
$\theta = 0.5$	0.6	(0.7 -0.8)	0.6	(0 - 0.5)	-	(0 - 1)	-
$\theta = 0.6$	0.6	(0.7 -0.8)	0.6	(0 - 0.6)	-	(0 - 1)	-
$\theta = 0.7$	0.6	(0.7 -0.8)	0.6	(0 - 0.7), 1	-	(0 - 1)	-
$\theta = 0.8$	-	(0.7 -0.8)	-	(0 - 1)	-	(0 - 1)	-
$\theta = 0.9$	-	(0.7 -0.8)	-	(0 - 1)	-	(0 - 1)	-
$\theta = 1.0$	-	(0.7 -0.8)	-	(0 - 1)	-	(0 - 1)	-

Note: Reported values are for the parameter β. Instrument sets are lags 1 to 4 of wage inflation (dw), the long-short interest rate spread (sp), inflation (dp), labour income share (s), quadratically detrended output gap (gq), commodity price inflation (dc), and cubically detrended output gap (gc).

Table 3a: Hybrid Model - Parameter Grid Search Results
Parameter Combinations that Do Not Reject H_0 - Full Sample

	dw_1 - dw_4										
	$\omega = 0$	$\omega = 0.1$	$\omega = 0.2$	$\omega = 0.3$	$\omega = 0.4$	$\omega = 0.5$	$\omega = 0.6$	$\omega = 0.7$	$\omega = 0.8$	$\omega = 0.9$	$\omega = 1.0$
$\theta = 0.0$	(0 - 1)	-	-	-	-	-	-	-	-	-	-
$\theta = 0.1$	(0.4 - 0.7)	(0.9 - 1)	-	-	-	-	-	-	-	-	-
$\theta = 0.2$	(0.5 - 0.6)	0.8	(0.9 - 1)	-	-	-	-	-	-	-	-
$\theta = 0.3$	0.6	0.7	0.8	-	-	-	-	-	-	-	-
$\theta = 0.4$	0.6	0.7	0.7	-	-	-	-	-	-	-	-
$\theta = 0.5$	0.6	0.7	0.7	-	-	-	-	-	-	-	-
$\theta = 0.6$	0.6	-	-	-	-	-	-	-	-	-	-
$\theta = 0.7$	0.6	0.6	0.6	-	-	-	-	-	-	-	-
$\theta = 0.8$	0.6	0.6	0.6	-	-	-	-	-	-	-	-
$\theta = 0.9$	0.6	0.6	0.6	-	-	-	-	-	-	-	-
$\theta = 1.0$	-	0.6	-	-	-	-	-	-	-	-	-
	sp_1 - sp_4										
$\theta = 0.0$	-	-	-	-	-	-	-	-	-	-	-
$\theta = 0.1$	-	-	-	-	-	-	-	-	-	-	-
$\theta = 0.2$	-	-	-	-	-	-	-	-	-	-	-
$\theta = 0.3$	-	-	-	-	-	-	-	-	-	-	-
$\theta = 0.4$	-	-	-	-	-	-	-	-	-	-	-
$\theta = 0.5$	-	-	-	-	0.6	-	-	-	-	-	-
$\theta = 0.6$	-	-	-	0.6	0.5	-	-	-	-	-	-
$\theta = 0.7$	-	0.6	0.6	0.6	0.5	-	-	-	-	-	-
$\theta = 0.8$	0.6	0.6	0.6	-	0.5	0.4	-	-	-	-	-
$\theta = 0.9$	0.6	0.6	0.6	0.5	-	0.4	0.3	-	-	-	-
$\theta = 1.0$	-	-	-	-	-	-	-	-	-	-	-

Note: Reported values are for the parameter β. Instrument sets are lags 1 to 4 of wage inflation (dw) and of the long-short interest rate spread (sp).

Table 3b: Hybrid Model - Parameter Grid Search Results
Parameter Combinations that Do Not Reject H_0 - Full Sample

	dp_2 - dp_5										
	$\omega = 0$	$\omega = 0.1$	$\omega = 0.2$	$\omega = 0.3$	$\omega = 0.4$	$\omega = 0.5$	$\omega = 0.6$	$\omega = 0.7$	$\omega = 0.8$	$\omega = 0.9$	$\omega = 1.0$
$\theta = 0.0$	(0-1)	-	-	-	-	-	-	-	-	-	-
$\theta = 0.1$	(0.3-0.7)	(0.8-1)	-	-	-	-	-	-	(0.7-1)	(0.3-0.5)	-
$\theta = 0.2$	(0.5-0.6)	(0.7-0.8)	(0.9-1)	1	1	(0.9-1)	(0.8-1)	(0.6-0.8)	(0.4-0.6)	0.2	-
$\theta = 0.3$	0.6	0.7	(0.7-0.8)	(0.8-0.9)	(0.7-0.9)	(0.7-0.8)	(0.6-0.7)	(0.4-0.6)	(0.3-0.4)	0.11	-
$\theta = 0.4$	0.6	0.7	0.7	0.7	(0.6-0.7)	(0.6-0.7)	(0.5-0.6)	0.4	(0.2-0.3)	0.11	-
$\theta = 0.5$	0.6	(0.6-0.7)	(0.6-0.7)	(0.6-0.7)	0.6	(0.5-0.6)	(0.4-0.5)	(0.3-0.4)	0.2	0.11	-
$\theta = 0.6$	0.6	0.6	0.6	0.6	(0.5-0.6)	(0.4-0.5)	0.4	0.3	0.2	-	-
$\theta = 0.7$	0.6	0.6	0.6	(0.5-0.6)	0.5	(0.4-0.5)	(0.3-0.4)	(0.2-0.3)	0.1	-	-
$\theta = 0.8$	-	0.6	0.6	0.5	0.5	0.4	0.3	0.2	0.1	-	-
$\theta = 0.9$	-	0.6	0.6	0.5	(0.4-0.5)	0.4	0.3	0.2	0.1	-	-
$\theta = 1.0$	-	0.6	0.6	0.5	0.4	(0.3-0.4)	0.3	0.2	0.1	-	-
	s_1 - s_4										
$\theta = 0.0$	-	-	-	-	-	-	-	-	-	0.3	0.8
$\theta = 0.1$	-	-	-	-	-	-	-	-	(0.6 - 1)	(0.1 - 0.6)	0
$\theta = 0.2$	-	-	-	-	-	1	0.9	(0.6 - 0.8)	(0.4 - 0.5)	(0.1 - 0.3)	0
$\theta = 0.3$	-	-	-	-	-	0.7	(0.6 - 0.7)	0.5	(0.3 - 0.4)	(0.1 - 0.2)	0
$\theta = 0.4$	-	-	-	0.7	0.7	0.6	0.5	0.4	(0.2-0.3)	0.1	0
$\theta = 0.5$	-	-	-	-	0.6	0.5	0.4	0.3	0.2	(0-0.1)	0
$\theta = 0.6$	-	-	0.6	0.6	-	0.5	0.4	0.3	0.2	(0-0.1)	0
$\theta = 0.7$	-	0.6	0.6	-	0.5	0.4	0.3	0.2	0.1	0	0
$\theta = 0.8$	-	0.6	0.6	-	0.5	0.4	0.3	0.2	0.1	0	0
$\theta = 0.9$	-	0.6	0.6	0.5	-	0.4	0.3	0.2	0.1	0	-
$\theta = 1.0$	-	0.6	-	0.5	-	-	0.3	0.2	0.1	0	-

Note: Reported values are for the parameter β. Instrument sets are lags 2 to 4 of inflation (dp) and lags 1 to 4 of labour income share (s).

Table 4a: Hybrid Model - Parameter Grid Search Results
Parameter Combinations that Do Not Reject H_0 - Sample period (1970Q1 to 1979Q4)

	dw_1 - dw_4										
	$\omega = 0$	$\omega = 0.1$	$\omega = 0.2$	$\omega = 0.3$	$\omega = 0.4$	$\omega = 0.5$	$\omega = 0.6$	$\omega = 0.7$	$\omega = 0.8$	$\omega = 0.9$	$\omega = 1.0$
$\theta = 0.0$	(0 - 1)	-	-	-	-	-	-	-	-	-	-
$\theta = 0.1$	0.8	-	-	-	-	-	-	-	-	-	-
$\theta = 0.2$	-	-	-	-	-	-	-	-	-	-	-
$\theta = 0.3$	-	0.9	1	1	-	-	-	-	-	-	-
$\theta = 0.4$	0.7	0.8	(0.8 - 0.9)	0.9	0.8	-	-	-	-	-	-
$\theta = 0.5$	(0.7 - 0.8)	0.8	0.8	0.8	0.7	-	-	-	-	-	-
$\theta = 0.6$	(0.7 - 0.8)	(0.7 - 0.8)	(0.7 - 0.8)	0.7	0.7	-	-	-	-	-	-
$\theta = 0.7$	(0.7 - 0.8)	(0.7 - 0.8)	0.7	0.7	0.6	-	-	-	-	-	-
$\theta = 0.8$	(0.7 - 0.8)	(0.7 - 0.8)	0.7	(0.6 - 0.7)	0.6	0.5	-	-	-	-	-
$\theta = 0.9$	(0.7 - 0.8)	0.7	(0.6 - 0.7)	0.6	0.5	-	-	-	-	-	-
$\theta = 1.0$	(0.7 - 0.8)	0.7	(0.6 - 0.7)	0.6	0.5	0.4	-	-	-	-	-
	sp_1 - sp_4										
$\theta = 0.0$	(0-1)	-	-	-	-	-	-	-	-	-	(0-1)
$\theta = 0.1$	(0.7-0.8)	-	-	-	-	-	-	-	(0.9-1)	(0.2 - 0.7)	(0-0.1)
$\theta = 0.2$	(0.7-0.8)	(0.9-1)	-	-	-	-	1	(0.8-1)	(0.5-0.7)	(0.1-0.3)	0
$\theta = 0.3$	(0.7-0.8)	(0.8-0.9)	(0.9-1)	(0.9-1)	(0.9-1)	(0.9-1)	(0.7-0.9)	(0.5-0.7)	(0.3-0.5)	(0.1-0.2)	0
$\theta = 0.4$	(0.7-0.8)	0.8	(0.8-0.9)	(0.8-0.9)	(0.8-0.9)	(0.7-0.8)	(0.6-0.7)	(0.4-0.5)	0.3	(0.1-0.2)	0
$\theta = 0.5$	(0.7-0.8)	(0.7-0.8)	0.8	(0.7-0.8)	(0.7-0.8)	(0.6-0.7)	(0.5-0.6)	0.4	(0.2-0.3)	0.1	0
$\theta = 0.6$	(0.7-0.8)	(0.7-0.8)	(0.7-0.8)	0.7	(0.6-0.7)	(0.5-0.6)	(0.4-0.5)	(0.3-0.4)	0.2	0.1	0
$\theta = 0.7$	(0.7-0.8)	(0.7-0.8)	0.7	(0.6-0.7)	0.6	0.5	0.4	0.3	0.2	0.1	0
$\theta = 0.8$	(0.7-0.8)	0.7	0.7	(0.6-0.7)	(0.5-0.6)	0.5	0.4	0.3	0.2	0.1	0
$\theta = 0.9$	(0.7-0.8)	0.7	(0.6-0.7)	0.6	(0.5-0.6)	(0.4-0.5)	(0.3-0.4)	0.2	0.2	-	0
$\theta = 1.0$	(0.7-0.8)	0.7	(0.6-0.7)	0.6	0.5	0.4	0.3	0.2	0.1	-	0

Note: Reported values are for the parameter β. Instrument sets are lags 1 to 4 of wage inflation (dw) and of the long-short interest rate spread (sp).

Table 4b: Hybrid Model - Parameter Grid Search Results
Parameter Combinations that Do Not Reject H_0 - Sample period (1970Q1 to 1979Q4)

	dp_2 - dp_5										
	$\omega = 0$	$\omega = 0.1$	$\omega = 0.2$	$\omega = 0.3$	$\omega = 0.4$	$\omega = 0.5$	$\omega = 0.6$	$\omega = 0.7$	$\omega = 0.8$	$\omega = 0.9$	$\omega = 1.0$
$\theta = 0.0$	(0-1)	-	-	-	-	-	-	-	-	(0-1)	(0-1)
$\theta = 0.1$	0.7	-	-	-	-	-	-	(0.9-1)	(0.4-1)	(0-1)	(0-0.6)
$\theta = 0.2$	0.7	(0.9-1)	-	-	-	1	(0.8-1)	(0.5-1)	(0.2-1)	(0-0.6)	(0-0.3)
$\theta = 0.3$	0.7	(0.8-0.9)	(0.9-1)	(0.9-1)	(0.8-1)	(0.7-1)	(0.6-1)	(0.4-0.9)	(0.2-0.7)	(0-0.4)	(0-0.2)
$\theta = 0.4$	(0.7-0.8)	(0.8-0.9)	(0.8-0.9)	(0.7-1)	(0.7-1)	(0.6-0.9)	(0.5-0.8)	(0.3-0.7)	(0.1-0.5)	(0-0.3)	(0-0.1)
$\theta = 0.5$	(0.7-0.8)	(0.7-0.8)	(0.7-0.9)	(0.7-0.9)	(0.6-0.8)	(0.5-0.8)	(0.5-0.7)	(0.3-0.6)	(0.1-0.4)	(0-0.2)	(0-0.1)
$\theta = 0.6$	(0.7-0.8)	(0.7-0.8)	(0.7-0.8)	(0.6-0.8)	(0.5-0.8)	(0.5-0.7)	(0.3-0.6)	(0.2-0.5)	(0.1-0.3)	(0-0.2)	(0-0.1)
$\theta = 0.7$	(0.7-0.8)	(0.7-0.8)	(0.6-0.8)	(0.6-0.8)	(0.5-0.7)	(0.4-0.6)	(0.3-0.5)	(0.2-0.4)	(0.1-0.3)	(0-0.2)	0
$\theta = 0.8$	(0.7-0.8)	(0.7-0.8)	(0.6-0.8)	(0.6-0.7)	(0.5-0.7)	(0.4-0.6)	(0.3-0.5)	(0.2-0.4)	(0.1-0.3)	(0-0.1)	0
$\theta = 0.9$	(0.7-0.8)	(0.7-0.8)	(0.6-0.7)	(0.5-0.7)	(0.5-0.6)	(0.4-0.5)	(0.3-0.4)	(0.2-0.3)	(0.1-0.2)	(0-0.1)	0
$\theta = 1.0$	(0.7-0.8)	(0.6-0.7)	(0.6-0.7)	(0.5-0.7)	(0.4-0.6)	(0.3-0.5)	(0.3-0.4)	(0.2-0.3)	(0.1-0.2)	(0-0.1)	0
	gq_1 - gq_4										
$\theta = 0.0$	-	-	-	-	-	-	-	-	-	-	-
$\theta = 0.1$	-	-	-	-	-	-	-	-	-	-	-
$\theta = 0.2$	-	-	-	-	-	-	-	-	-	-	-
$\theta = 0.3$	-	-	-	-	-	-	-	-	-	-	-
$\theta = 0.4$	-	-	-	-	-	-	-	-	-	-	-
$\theta = 0.5$	-	-	-	-	-	-	-	-	-	-	-
$\theta = 0.6$	-	-	-	-	-	-	-	-	-	-	-
$\theta = 0.7$	-	-	-	-	-	-	-	-	-	-	-
$\theta = 0.8$	-	-	-	-	-	-	-	-	-	-	-
$\theta = 0.9$	-	-	-	-	-	-	-	-	-	-	-
$\theta = 1.0$	-	-	-	-	-	-	-	-	-	-	-

Note: Reported values are for the parameter β. Instrument sets are lags 2 to 4 of inflation (dp) and lags 1 to 4 of quadratically detrended output gap (gq).

Table 5a: Hybrid Model - Parameter Grid Search Results
Parameter Combinations that Do Not Reject H_0 - Sample period (1980Q1 to 1989Q4)

	dw_1 - dw_4										
	$\omega = 0$	$\omega = 0.1$	$\omega = 0.2$	$\omega = 0.3$	$\omega = 0.4$	$\omega = 0.5$	$\omega = 0.6$	$\omega = 0.7$	$\omega = 0.8$	$\omega = 0.9$	$\omega = 1.0$
$\theta = 0.0$	(0-1)	(0.5-1)	-	-	-	-	-	-	-	(0.6-1)	-
$\theta = 0.1$	(0.1-0.6)	(0.6-1)	(0.9-1)	-	-	-	1	(0.8-1)	(0.5-0.9)	(0.1-0.4)	-
$\theta = 0.2$	(0.4-0.6)	(0.5-0.7)	(0.7-0.9)	(0.7-0.9)	(0.7-1)	(0.7-0.9)	(0.6-0.8)	(0.5-0.6)	(0.3-0.4)	(0.1-0.2)	-
$\theta = 0.3$	0.5	(0.5-0.6)	(0.6-0.7)	(0.6-0.7)	(0.6-0.7)	(0.5-0.7)	(0.4-0.6)	(0.3-0.4)	(0.2-0.3)	0.1	-
$\theta = 0.4$	0.5	(0.5-0.6)	(0.5-0.6)	(0.5-0.6)	(0.5-0.6)	(0.4-0.5)	0.4	0.3	0.2	0.1	-
$\theta = 0.5$	0.5	(0.5-0.6)	(0.5-0.6)	(0.5-0.6)	(0.4-0.5)	0.4	(0.3-0.4)	(0.2-0.3)	(0.1-0.2)	-	-
$\theta = 0.6$	0.5	0.5	0.5	(0.4-0.5)	(0.4-0.5)	(0.3-0.4)	0.3	0.2	0.1	-	-
$\theta = 0.7$	0.5	0.5	0.5	(0.4-0.5)	0.4	(0.3-0.4)	0.3	0.2	0.1	-	-
$\theta = 0.8$	0.5	0.5	(0.4-0.5)	(0.4-0.5)	0.4	0.3	0.2	0.2	0.1	-	-
$\theta = 0.9$	0.5	0.5	(0.4-0.5)	0.4	(0.3-0.4)	0.3	0.2	-	0.1	-	-
$\theta = 1.0$	0.5	0.5	(0.4-0.5)	0.4	(0.3-0.4)	0.3	0.2	-	0.1	-	-
	sp_1 - sp_4										
$\theta = 0.0$	(0-1)	(0.7-1)	-	-	-	-	-	-	-	(0-1)	(0-1)
$\theta = 0.1$	(0.2-0.6)	(0.6-1)	(0.9-1)	(0.7-0.9)	(0.7-1)	-	(0.9-1)	(0.6-1)	(0.3-1)	(0-0.6)	(0-0.1)
$\theta = 0.2$	(0.4-0.6)	(0.5-0.7)	(0.6-0.9)	(0.6-0.7)	(0.5-0.7)	(0.6-1)	(0.5-0.9)	(0.4-0.7)	(0.2-0.5)	(0-0.3)	0
$\theta = 0.3$	0.5	(0.5-0.6)	(0.6-0.7)	(0.5-0.6)	(0.5-0.6)	(0.5-0.7)	(0.4-0.6)	(0.3-0.5)	(0.1-0.3)	(0-0.1)	0
$\theta = 0.4$	0.5	(0.5-0.6)	(0.5-0.6)	(0.5-0.6)	(0.4-0.5)	(0.4-0.5)	(0.3-0.5)	(0.2-0.4)	(0.1-0.3)	(0-0.1)	0
$\theta = 0.5$	0.5	(0.5-0.6)	(0.5-0.6)	(0.4-0.5)	(0.4-0.5)	(0.4-0.5)	(0.3-0.4)	(0.2-0.3)	(0.1-0.2)	(0-0.1)	0
$\theta = 0.6$	0.5	0.5	0.5	(0.4-0.5)	0.4	(0.3-0.4)	0.3	(0.2-0.3)	(0.1-0.2)	(0-0.1)	0
$\theta = 0.7$	0.5	0.5	0.5	(0.4-0.5)	(0.3-0.4)	(0.3-0.4)	(0.2-0.3)	0.2	0.1	(0-0.1)	0
$\theta = 0.8$	0.5	0.5	(0.4-0.5)	(0.4-0.5)	(0.3-0.4)	0.3	(0.2-0.3)	0.2	0.1	0	0
$\theta = 0.9$	0.5	0.5	(0.4-0.5)	0.4	(0.3-0.4)	0.3	0.2	(0.1-0.2)	0.1	0	0
$\theta = 1.0$	0.5	0.5	(0.4-0.5)	0.4	(0.3-0.4)	0.3	0.2	(0.1-0.2)	0.1	0	0

Note: Reported values are for the parameter β. Instrument sets are lags 1 to 4 of wage inflation (dw) and of the long-short interest rate spread (sp).

Table 5b: Hybrid Model - Parameter Grid Search Results
Parameter Combinations that Do Not Reject H_0 - Sample period (1980Q1 to 1989Q4)

	dp_2 - dp_5										
	$\omega = 0$	$\omega = 0.1$	$\omega = 0.2$	$\omega = 0.3$	$\omega = 0.4$	$\omega = 0.5$	$\omega = 0.6$	$\omega = 0.7$	$\omega = 0.8$	$\omega = 0.9$	$\omega = 1.0$
$\theta = 0.0$	(0-1)	(0.8-1)	-	-	-	-	-	-	-	(0.2-1)	(0-0.2)
$\theta = 0.1$	(0.2-0.6)	(0.6-7)	1	-	-	-	-	(0.8-1)	(0.5-0.9)	(0.1-0.4)	0
$\theta = 0.2$	(0.4-0.5)	0.6	(0.7-0.8)	0.8	(0.8-0.9)	(0.7-9)	(0.6-0.8)	(0.5-0.6)	(0.3-0.4)	(0-0.2)	0
$\theta = 0.3$	0.5	0.5	0.6	(0.6-0.7)	(0.6-0.7)	(0.5-0.6)	0.5	(0.3-0.4)	(0.2-0.3)	(0-0.1)	-
$\theta = 0.4$	0.5	0.5	0.6	0.6	0.5	0.5	0.4	0.3	0.2	(0-0.1)	-
$\theta = 0.5$	0.5	0.5	0.5	0.5	0.5	0.4	(0.3-0.4)	0.2	(0.1-0.2)	(0-0.1)	-
$\theta = 0.6$	0.5	0.5	0.5	0.5	0.4	0.4	0.3	0.2	0.1	0	-
$\theta = 0.7$	0.5	0.5	0.5	0.4	0.4	0.3	0.3	0.2	0.1	0	-
$\theta = 0.8$	0.5	0.5	0.5	0.4	0.4	0.3	0.2	0.2	0.1	0	-
$\theta = 0.9$	0.5	0.5	0.5	0.4	(0.3-0.4)	0.3	0.2	0.2	0.1	0	-
$\theta = 1.0$	0.5	0.5	0.5	0.4	0.3	0.3	0.2	-	0.1	0	-
	gq_1 - gq_4										
$\theta = 0.0$	-	-	-	-	-	-	-	-	-	(0 - 1)	(0 - 1)
$\theta = 0.1$	-	-	-	-	-	-	-	(0.9 - 1)	(0.4 - 0.8)	(0 - 0.5)	(0 - 0.1)
$\theta = 0.2$	-	-	-	-	-	-	-	0.5	(0.2 - 0.4)	(0 - 0.2)	0
$\theta = 0.3$	-	-	-	-	-	-	-	0.4	(0.2 - 0.3)	(0 - 0.1)	0
$\theta = 0.4$	-	-	-	-	-	-	-	0.3	0.2	(0 - 0.1)	0
$\theta = 0.5$	-	-	-	-	-	-	-	-	0.1	(0 - 0.1)	0
$\theta = 0.6$	-	-	-	-	-	-	-	0.2	0.1	0	0
$\theta = 0.7$	-	-	-	-	-	-	-	0.2	0.1	0	0
$\theta = 0.8$	-	-	-	-	-	-	-	-	0.1	0	0
$\theta = 0.9$	-	-	-	-	-	-	-	-	0.1	0	0
$\theta = 1.0$	-	-	-	-	-	-	-	-	0.1	0	0

Note: Reported values are for the parameter β. Instrument sets are lags 2 to 4 of inflation (dp) and lags 1 to 4 of quadratically detrended output gap (gq).

Table 6a: Hybrid Model - Parameter Grid Search Results
Parameter Combinations that Do Not Reject H_0 - Sample period (1990Q1 to 1997Q4)

	dw_1 - dw_4										
	$\omega = 0$	$\omega = 0.1$	$\omega = 0.2$	$\omega = 0.3$	$\omega = 0.4$	$\omega = 0.5$	$\omega = 0.6$	$\omega = 0.7$	$\omega = 0.8$	$\omega = 0.9$	$\omega = 1.0$
$\theta = 0.0$	(0-1)	(0-1)	-	-	-	-	-	-	(0-1)	(0-1)	(0-1)
$\theta = 0.1$	(0-1)	(0.5-1)	1	-	-	-	(0.9-1)	(0.4-1)	(0-1)	(0-1)	(0-0.5)
$\theta = 0.2$	(0.4-0.9)	(0.6-1)	(0.8-1)	(0.9-1)	(0.8-1)	(0.7-1)	(0.5-1)	(0.3-1)	(0-1)	(0-0.6)	(0-0.2)
$\theta = 0.3$	(0.6-0.8)	(0.7-1)	(0.7-1)	(0.7-1)	(0.7-1)	(0.5-1)	(0.4-1)	(0.2-0.9)	(0-0.7)	(0-0.4)	(0-0.1)
$\theta = 0.4$	(0.6-0.8)	(0.7-0.9)	(0.7-1)	(0.6-1)	(0.6-1)	(0.5-0.9)	(0.3-0.8)	(0.2-0.7)	(0-0.5)	(0-0.3)	(0-0.1)
$\theta = 0.5$	(0.6-0.8)	(0.6-0.9)	(0.6-0.9)	(0.6-0.9)	(0.5-0.9)	(0.4-0.8)	(0.3-0.7)	(0.1-0.6)	(0-0.4)	(0-0.2)	(0-0.1)
$\theta = 0.6$	(0.7-0.8)	(0.6-0.8)	(0.6-0.8)	(0.5-0.8)	(0.5-0.8)	(0.4-0.7)	(0.3-0.6)	(0.1-0.5)	(0-0.3)	(0-0.2)	0
$\theta = 0.7$	(0.7-0.8)	(0.6-0.8)	(0.6-0.8)	(0.5-0.8)	(0.4-0.7)	(0.3-0.6)	(0.2-0.5)	(0.1-0.4)	(0-0.3)	(0-0.2)	0
$\theta = 0.8$	(0.7-0.8)	(0.6-0.8)	(0.6-0.8)	(0.5-0.7)	(0.4-0.7)	(0.3-0.6)	(0.2-0.5)	(0.1-0.4)	(0-0.2)	(0-0.1)	0
$\theta = 0.9$	(0.7-0.8)	(0.6-0.8)	(0.6-0.8)	(0.5-0.7)	(0.4-0.6)	(0.3-0.6)	(0.2-0.4)	(0.1-0.3)	(0-0.2)	(0-0.1)	0
$\theta = 1.0$	(0.7-0.8)	(0.6-0.8)	(0.5-0.7)	(0.5-0.7)	(0.4-0.6)	(0.3-0.5)	(0.2-0.4)	(0.1-0.3)	(0-0.2)	(0-0.1)	0
	sp_1 - sp_4										
$\theta = 0.0$	(0-1)	(0.7-1)	(0.8-1)	-	-	-	-	-	(0-1)	(0-1)	(0-1)
$\theta = 0.1$	(0.3-0.8)	(0.7-1)	(0.7-1)	-	-	-	(0.8-1)	(0.3-1)	(0-1)	(0-1)	(0-0.7)
$\theta = 0.2$	(0.5-0.8)	(0.7-0.9)	(0.7-1)	(0.9-1)	(0.8-1)	(0.7-1)	(0.5-1)	(0.2-1)	(0-1)	(0-0.7)	(0-0.3)
$\theta = 0.3$	(0.6-0.8)	(0.7-0.9)	(0.7-0.9)	(0.7-1)	(0.6-1)	(0.5-1)	(0.4-1)	(0.1-1)	(0-0.7)	(0-0.4)	(0-0.2)
$\theta = 0.4$	(0.6-0.8)	(0.7-0.8)	(0.5-0.9)	(0.6-1)	(0.6-1)	(0.4-0.9)	(0.3-0.8)	(0.2-0.7)	(0-0.5)	(0-0.3)	(0-0.1)
$\theta = 0.5$	(0.6-0.8)	(0.7-0.8)	(0.6-0.8)	(0.6-0.9)	(0.5-0.8)	(0.5-0.8)	(0.3-0.7)	(0.1-0.6)	(0-0.4)	(0-0.3)	(0-0.1)
$\theta = 0.6$	(0.7-0.8)	(0.7-0.8)	(0.6-0.8)	(0.6-0.8)	(0.5-0.7)	(0.4-0.7)	(0.2-0.6)	(0.1-0.5)	(0-0.3)	(0-0.2)	(0-0.1)
$\theta = 0.7$	0.7	(0.7-0.8)	(0.6-0.7)	(0.5-0.7)	(0.4-0.7)	(0.3-0.6)	(0.2-0.5)	(0.1-0.4)	(0-0.3)	(0-0.2)	(0-0.1)
$\theta = 0.8$	0.7	(0.7-0.8)	(0.6-0.7)	(0.5-0.7)	(0.4-0.6)	(0.3-0.6)	(0.2-0.5)	(0.1-0.4)	(0-0.3)	(0-0.1)	0
$\theta = 0.9$	0.7	(0.6-0.7)	(0.6-0.7)	(0.5-0.7)	(0.4-0.6)	(0.3-0.5)	(0.2-0.4)	(0.1-0.3)	(0-0.2)	(0-0.1)	0
$\theta = 1.0$	0.7	(0.6-0.7)	(0.6-0.7)	(0.5-0.7)	(0.4-0.6)	(0.3-0.5)	(0.2-0.4)	(0.1-0.3)	(0-0.2)	(0-0.1)	0

Note: Reported values are for the parameter β. Instrument sets are lags 1 to 4 of wage inflation (dw) and of the long-short interest rate spread (sp).

Table 6b: Hybrid Model - Parameter Grid Search Results
Parameter Combinations that Do Not Reject H_0 - Sample period (1990Q1 to 1997Q4)

	dp_2 - dp_5										
	$\omega = 0$	$\omega = 0.1$	$\omega = 0.2$	$\omega = 0.3$	$\omega = 0.4$	$\omega = 0.5$	$\omega = 0.6$	$\omega = 0.7$	$\omega = 0.8$	$\omega = 0.9$	$\omega = 1.0$
$\theta = 0.0$	(0 - 1)	(0 - 1)	-	-	-	-	-	-	-	-	-
$\theta = 0.1$	(0 - 1)	(0.5 - 1)	-	-	-	-	-	-	-	-	-
$\theta = 0.2$	(0.4 - 0.8)	(0.7 - 1)	(0.9 - 1)	-	-	-	-	-	-	-	-
$\theta = 0.3$	(0.6 - 0.7)	0.8	0.9	-	-	-	-	-	-	-	-
$\theta = 0.4$	-	-	0.9	-	-	-	-	-	-	-	-
$\theta = 0.5$	-	-	0.9	-	-	-	-	-	-	-	-
$\theta = 0.6$	-	-	-	-	-	-	-	-	-	-	-
$\theta = 0.7$	-	-	-	-	-	-	-	-	-	-	-
$\theta = 0.8$	-	-	-	-	-	-	-	-	-	-	-
$\theta = 0.9$	-	-	-	-	-	-	-	-	-	-	-
$\theta = 1.0$	-	-	-	-	-	-	-	-	-	-	-
	gq_1 - gq_4										
$\theta = 0.0$	-	-	-	-	-	-	-	-	-	(0-1)	(0-0.9)
$\theta = 0.1$	-	-	-	-	-	-	-	1	(0.5-1)	(0-0.7)	0
$\theta = 0.2$	-	-	1	-	1	(0.9-1)	(0.8-1)	(0.5-1)	(0.3-0.7)	(0-0.4)	0
$\theta = 0.3$	0.7	(0.8-0.9)	(0.8-1)	(0.8-1)	(0.8-1)	(0.7-1)	(0.5-0.9)	(0.4-0.7)	(0.2-0.5)	(0-0.2)	0
$\theta = 0.4$	(0.7-0.8)	(0.7-0.9)	(0.7-0.9)	(0.7-1)	(0.6-0.9)	(0.6-0.9)	(0.4-0.7)	(0.3-0.6)	(0.1-0.4)	(0-0.2)	0
$\theta = 0.5$	(0.7-0.8)	(0.7-0.8)	(0.7-0.9)	(0.6-0.9)	(0.6-0.8)	(0.5-0.7)	(0.4-0.6)	(0.2-0.5)	(0.1-0.3)	(0-0.1)	0
$\theta = 0.6$	(0.7-0.8)	(0.7-0.8)	(0.6-0.8)	(0.6-0.8)	(0.5-0.7)	(0.4-0.7)	(0.3-0.5)	(0.2-0.4)	(0.1-0.3)	(0-0.1)	0
$\theta = 0.7$	(0.7-0.8)	(0.7-0.8)	(0.6-0.8)	(0.6-0.7)	(0.5-0.7)	(0.4-0.6)	(0.3-0.5)	(0.2-0.4)	(0.1-0.2)	(0-0.1)	0
$\theta = 0.8$	(0.7-0.8)	(0.7-0.8)	(0.6-0.7)	(0.5-0.7)	(0.5-0.6)	(0.4-0.6)	(0.3-0.4)	(0.2-0.3)	(0.1-0.2)	(0-0.1)	-
$\theta = 0.9$	0.7	(0.6-0.7)	(0.6-0.7)	(0.5-0.7)	(0.4-0.6)	(0.3-0.5)	(0.3-0.4)	(0.2-0.3)	(0.1-0.2)	(0-0.1)	-
$\theta = 1.0$	0.7	(0.6-0.7)	(0.6-0.7)	(0.5-0.6)	(0.4-0.6)	(0.3-0.5)	(0.2-0.3)	(0.2-0.3)	(0.1-0.2)	0	-

Note: Reported values are for the parameter β. Instrument sets are lags 2 to 4 of inflation (dp) and lags 1 to 4 of quadratically detrended output gap (gq).

Figure 1: Benchmark Model - Full Sample

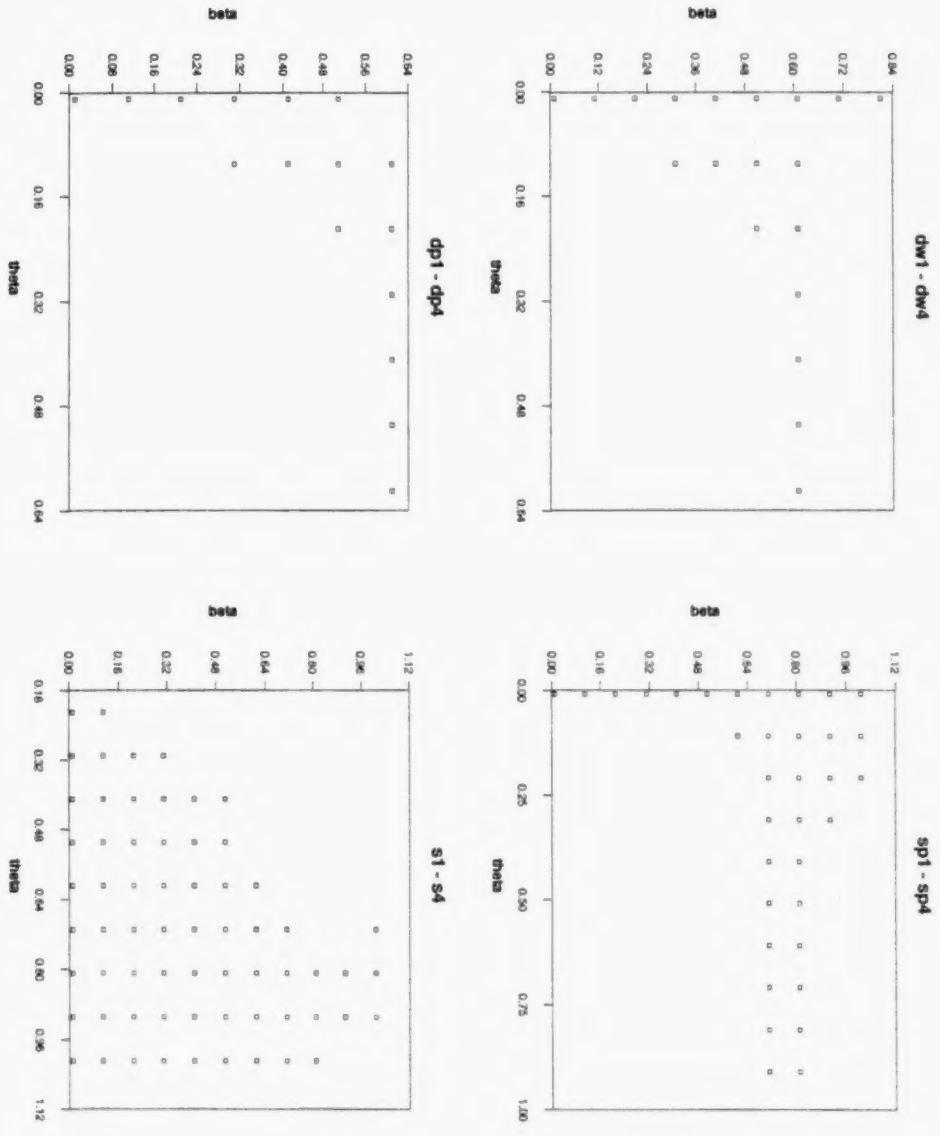


Figure 2: Hybrid Model - Full Sample

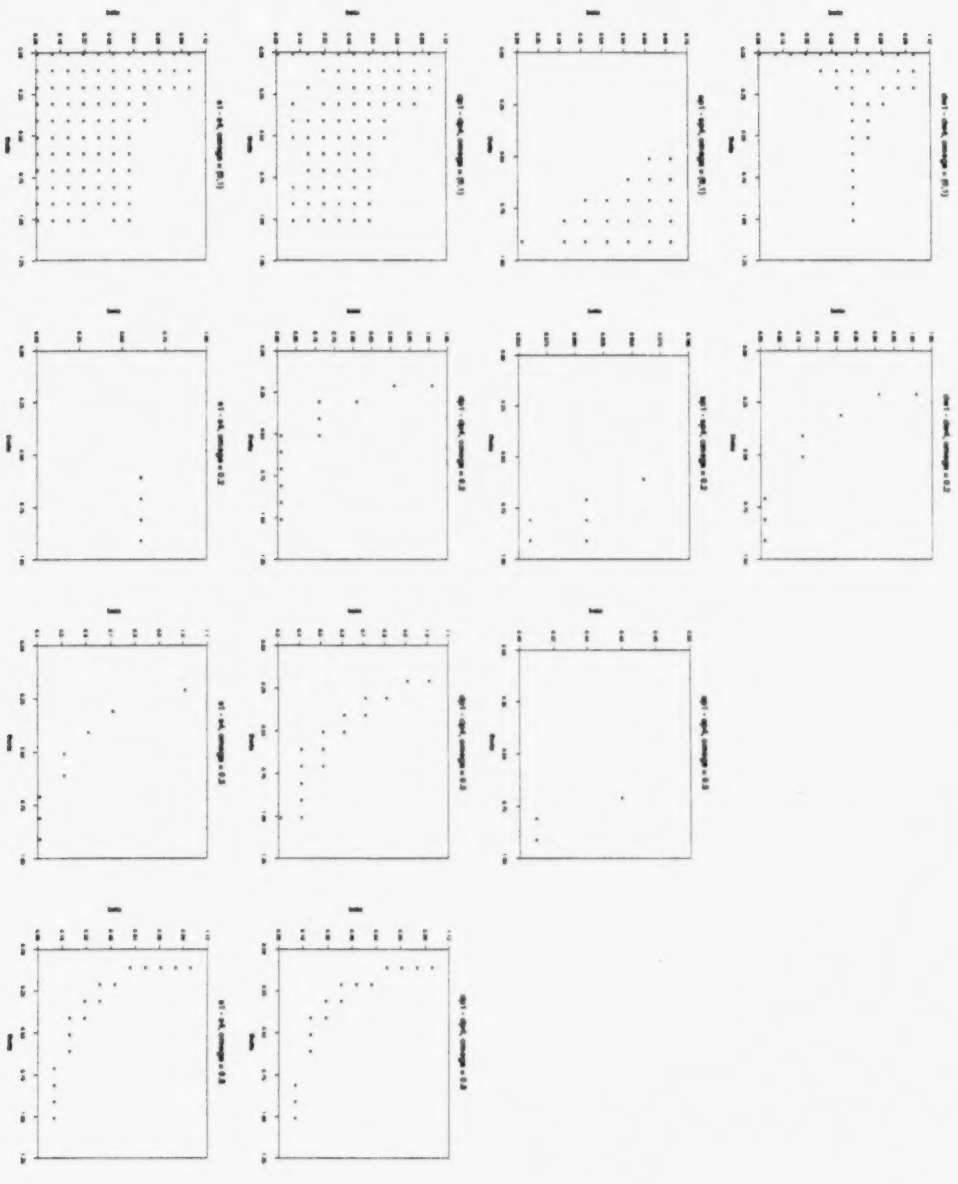


Figure 3: Constrained Hybrid Model - Full Sample
(no parameter combinations exist with the sp instruments)

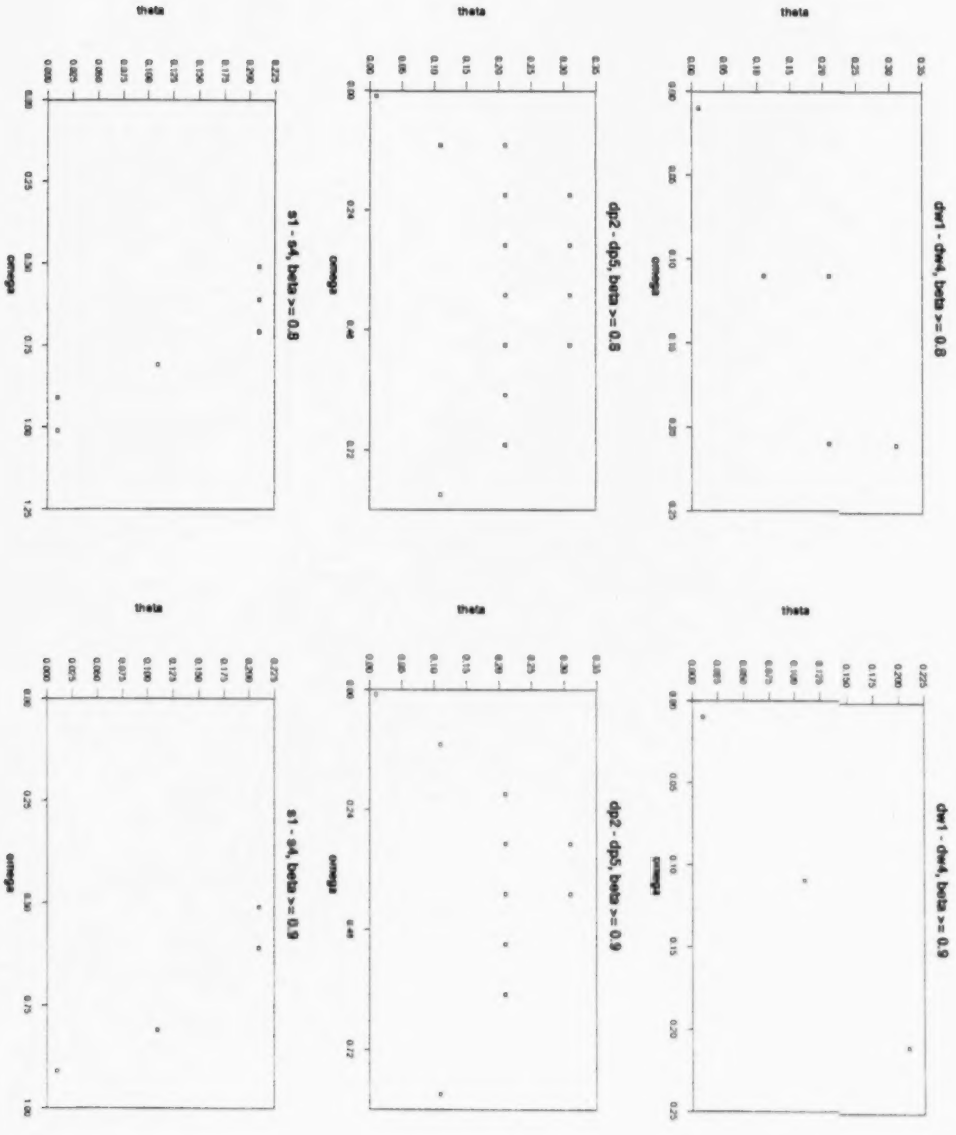


Figure 4: Hybrid Model - 1970Q1 to 1979Q4
(all parameter combinations reject with the gq instruments)

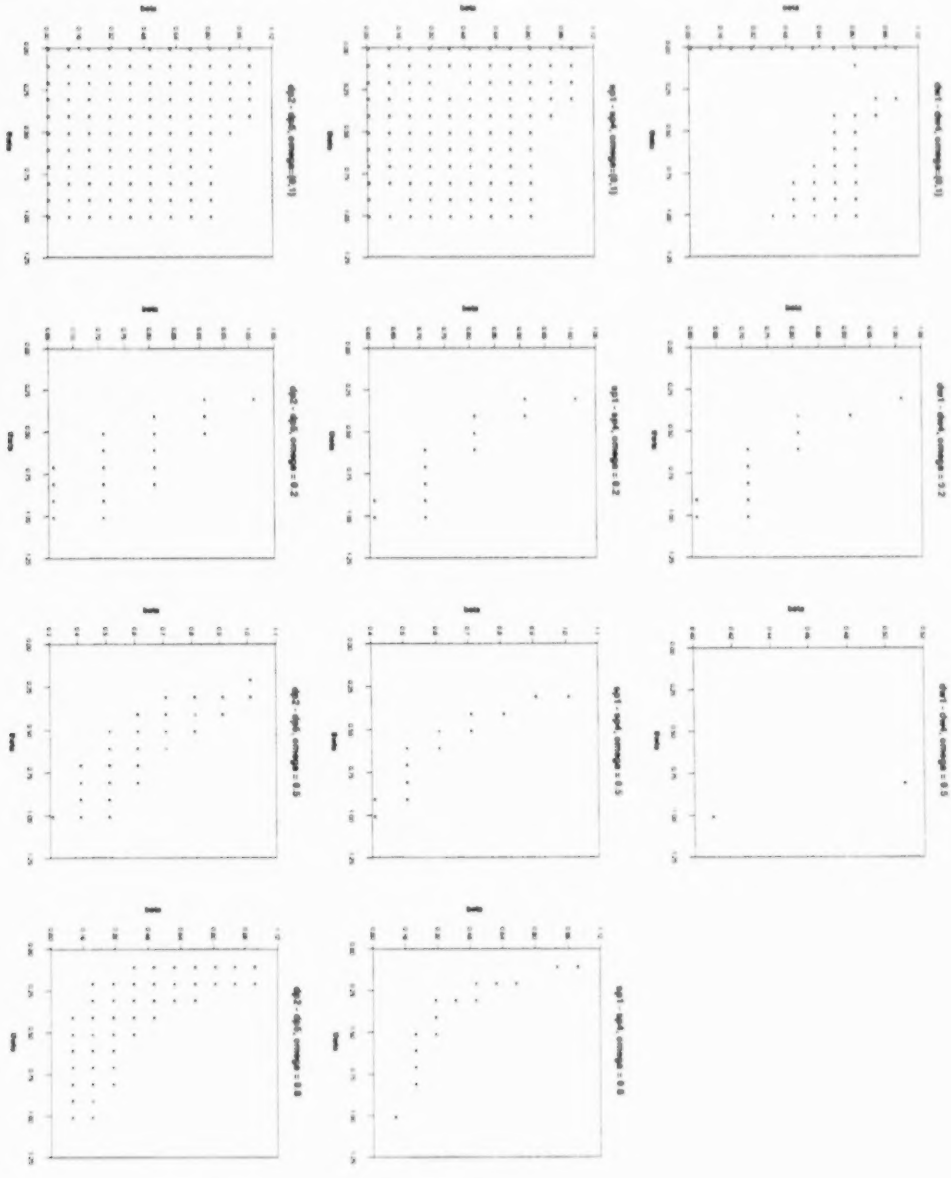


Figure 5: Constrained Hybrid Model - 1970Q1 to 1979Q4
(all parameter combinations reject with the gq instruments)

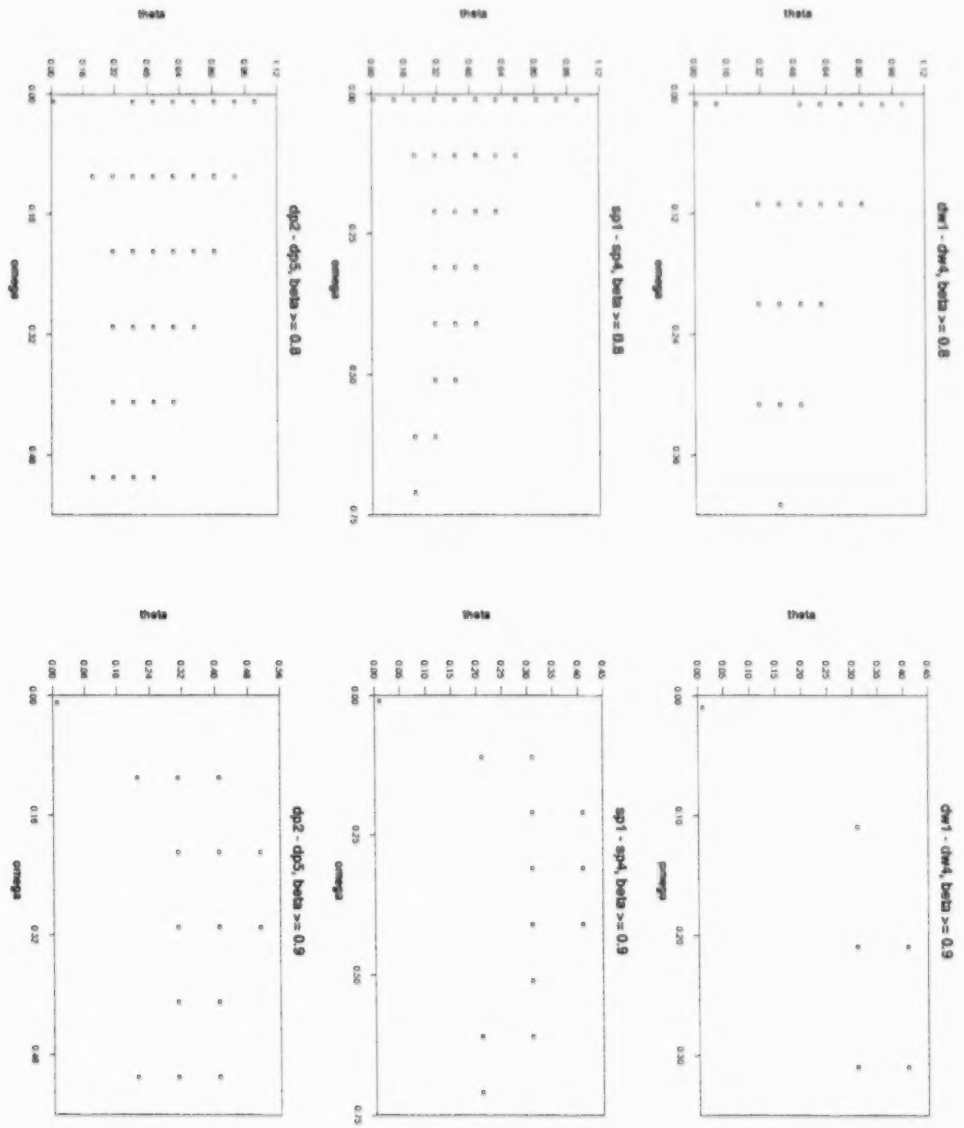


Figure 6: Hybrid Model - 1980Q1 to 1989Q4

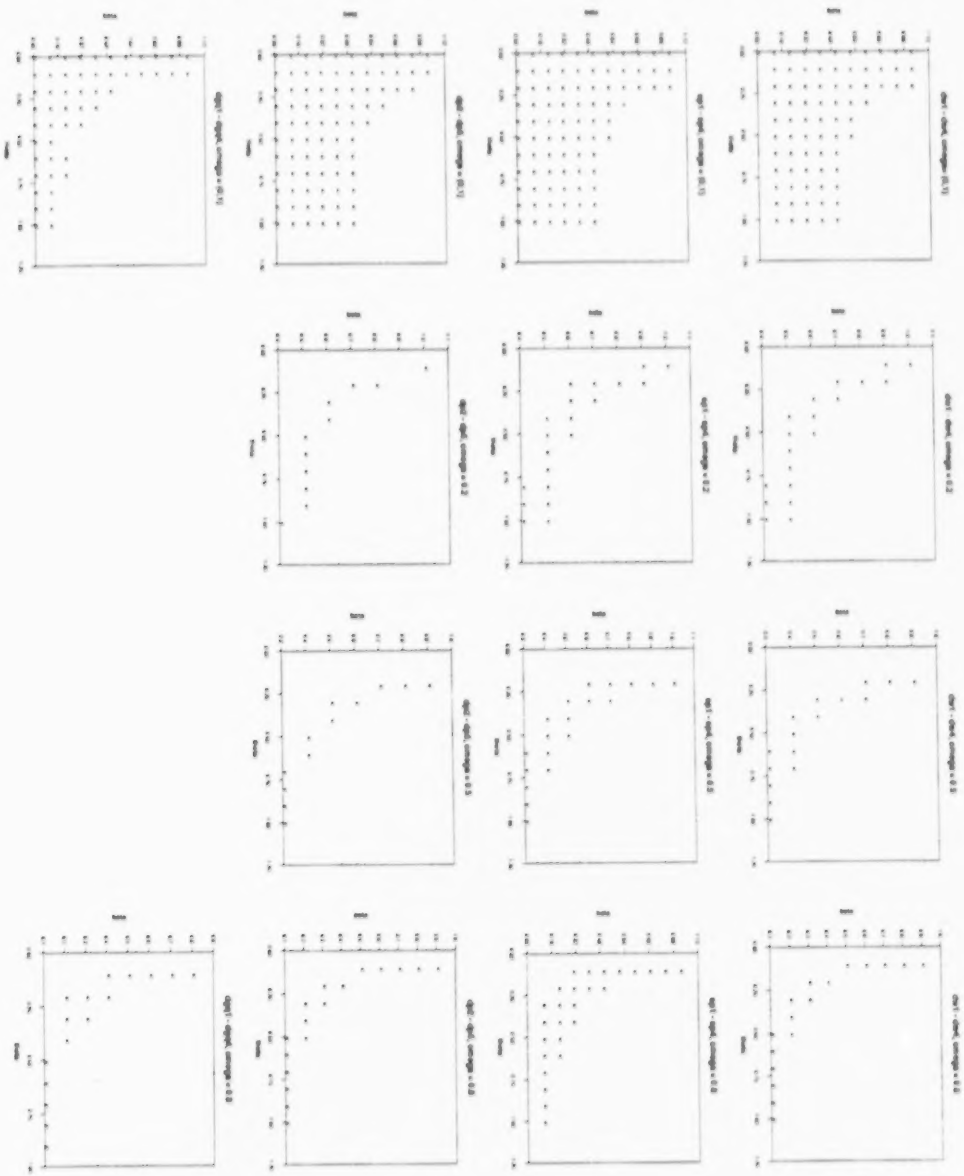


Figure 7: Constrained Hybrid Model - 1980Q1 to 1989Q4

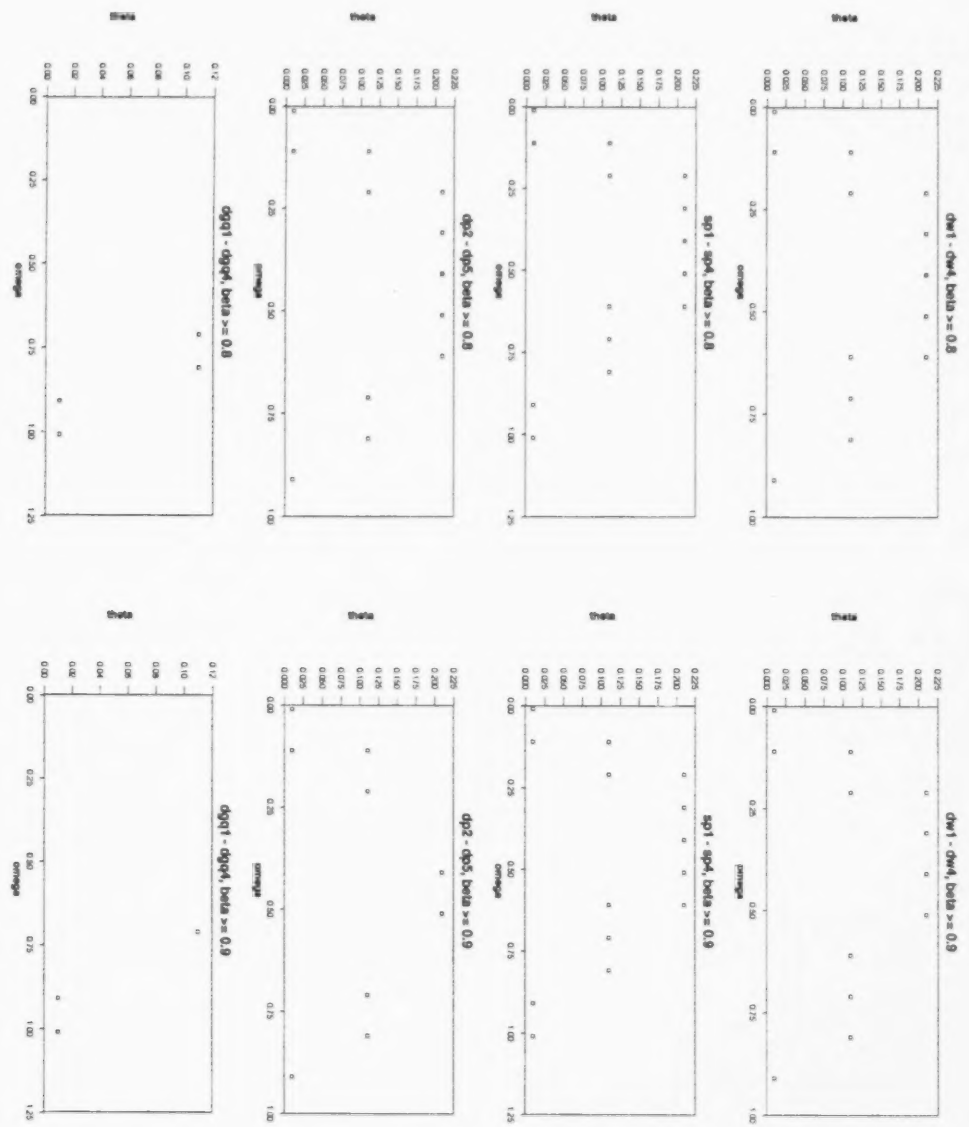

theta
omega
dgp1 - dgp4, beta >= 0.8
dp2 - dp5, beta >= 0.8
sp1 - sp4, beta >= 0.8
dw1 - dw4, beta >= 0.8
dgp1 - dgp4, beta >= 0.9
dp2 - dp5, beta >= 0.9
sp1 - sp4, beta >= 0.9
dw1 - dw4, beta >= 0.9

Figure 8: Hybrid Model - 1990Q1 to 1997Q4

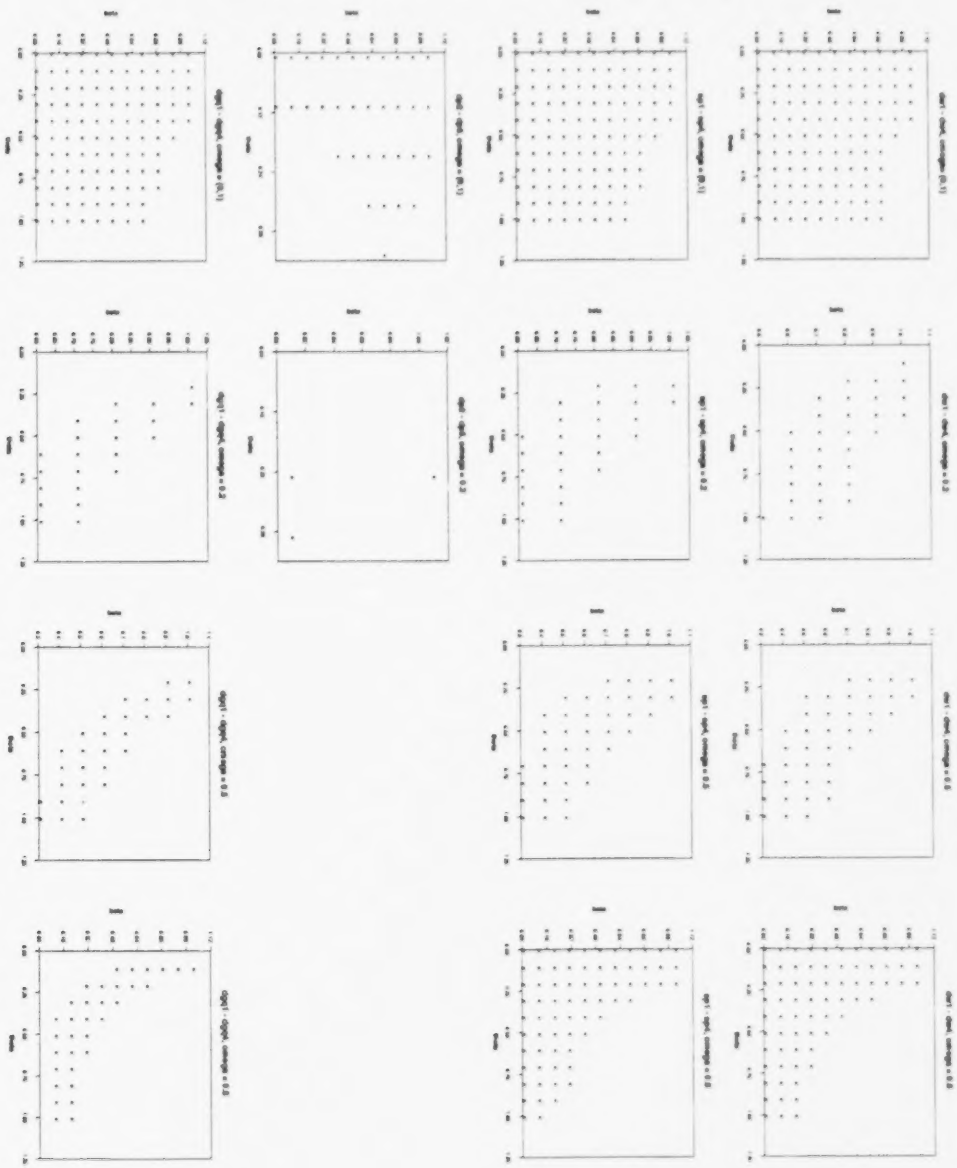
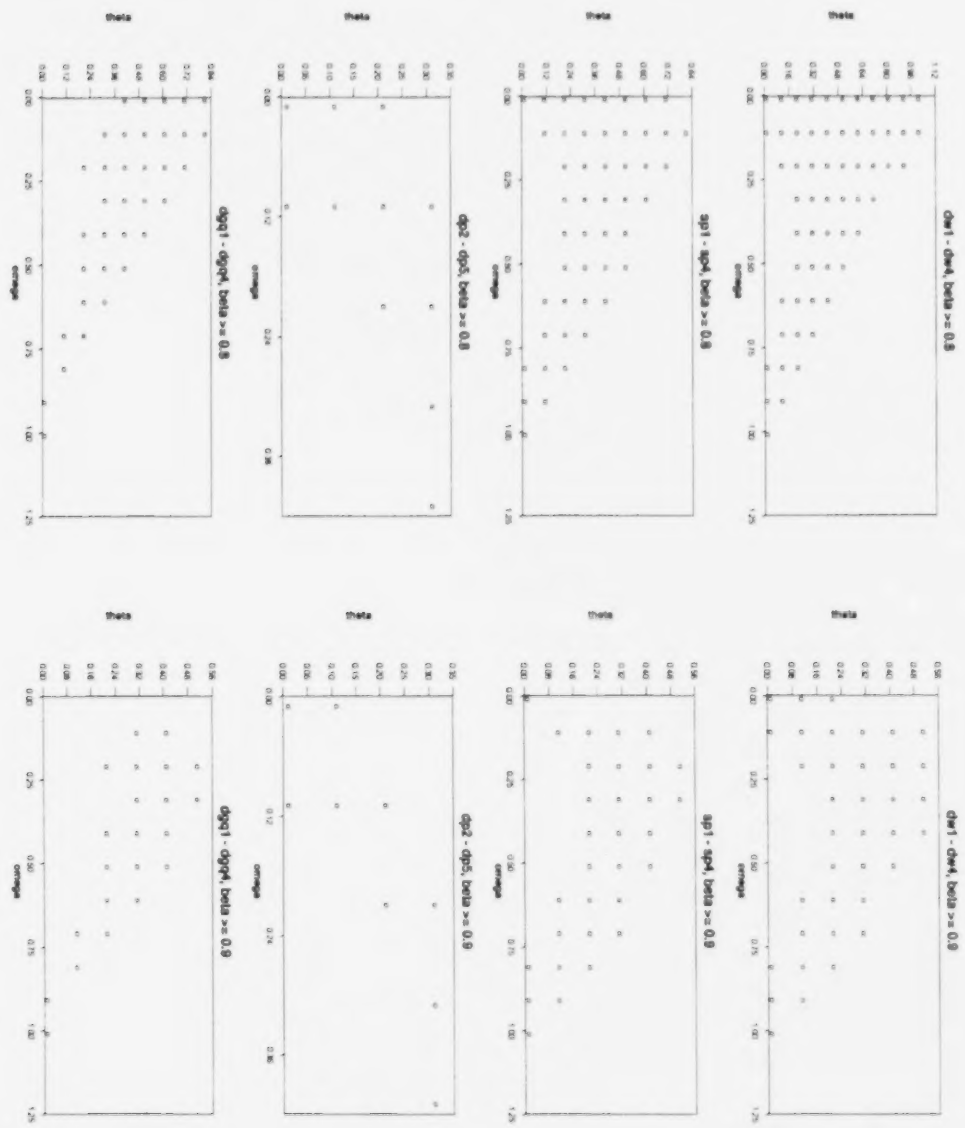


Figure 9: Constrained Hybrid Model - 1990Q1 to 1997Q4



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